Proceedings of the Second European Academic Research Conference on Global Business, Economics, Finance and Banking (EAR15Swiss Conference) ISBN: 978-1-63415-477-2
Zurich-Switzerland, 3-5 July, 2015 Paper ID: Z5104

Contemporaneous Spillover among Commodity Volatility Indices

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Abstract

This paper aims at examining the spillover effect in Eurocurrency, Gold, and Oil, with CBOE's implied volatility from 1 August 2008 to 1 December 2013. Using the identification through heteroskedasticity and structural vector autoregressive model approach of Badshah et al. (2013), this study has found that there were contemporaneous interactions between these variables and the bi-directional instantaneous spill-over among the three implied volatility indices. Thus, it could be interpreted that the investor in commodities market were sensitive to other markets.

Key words: *CBOE's volatility index, spillover, volatility transmission, commodity markets*
JEL Classification: *C 19, G 14*

1. Introduction

The interest in commodities is not a new issue in the financial economic world. Upon the strong fluctuation of the prices of commodity assets, more investments have been moved to those assets such as crude oil and gold particularly on the belief that gold is a safe asset and can diversify the portfolio risk. Gold is one of the most popular precious metals that can determine the price level of other commodities. Investors often have gold in hands during a disastrous situation like war or economic crisis thanks to its less price volatility when compared to stocks. Therefore, the gold trading market has longer history compared to those of other instruments. Likewise, crude oil plays an important role as a raw material in almost every industrial section especially the petrochemical one. The crude oil prices have kept increasing for a long period since 2000. Hence, crude oil prices have been highly volatile with active trading activities.

Today commodity prices have been more volatile. Both crude oil and gold markets have been increasingly liquid because of higher investments. Gold and crude oil are two good representatives of the commodities on the ground that gold and crude oil prices are associated with financial crises. In 2008, a global financial turbulence called the "hamburger crisis" largely shook the prices of gold and crude oil. The price of gold and crude oil showed a large swing. The gold price in January 2008 is about 1000 dollars per ounce and decline to about 700 dollars per ounces in January 2009 while the crude oil price also greatly decline, the price in January 2008 is about 140 dollars per barrel and decline to about 40 dollars per barrel in January 2009. As a result, the economies worldwide swirled and signified the importance of the information transmission and trade flow among the assets in the financial studies. To correct the allocation of the portfolio for hedging strategies or for asset diversification, investors need to understand the information transmission and trade flow among commodities.

Many researches have examined such relationship, and the investigation on the spill-over effect between crude oil and gold prices needs consider the exchange rate as one factor that may affects crude oil and gold prices volatility and vice versa. For example, oil is denominated in US dollars, depreciate U.S. dollar might lead to an increase in the demand for oil in non-dollar economies, which would cause the oil price to rise. While, gold also denominated in US dollars; appreciation of the US dollar will suppress gold prices. As stated in Sari et al. (2010), oil and the precious metals are denominated in US dollar, and thus, the dollar exchange rate may co-drive both of them simultaneously. During the expected inflation, investors may move from dollar-denominated soft assets such as stocks to dollar-denominated physical assets such as oil and the precious metals. It is well known that investors use precious metals, as a safe haven in their flight to safety when the US dollar weakens against the other major currencies, especially euro. It has become more evident recently that a depreciating dollar against the euro can also push up oil prices. Therefore, it will be informative and useful to traders, investors and policy makers to understand the dynamics and the relationships between the major precious metals, oil prices and exchange rates.

To examine the relationship, volatility is one of the variables which can examine the information transmission across different markets because volatility is regarded as a measure of risk. Volatility is difficult to observe but can be estimated by some processes. Those processes include implied volatility, historical volatility and return based volatility. Prior findings suggested that implied volatility outperformed other methods. As surveyed by Li and Yang (2008), their research examined the relationship between implied volatility and subsequently realized volatility. They found that the implied volatility was superior to historical volatility. In addition, Blair et al. (2001) compared the information content between implied volatility and high-frequency index return (return based volatility). Their papers compared in context of forecasting index volatility which concluded that implied volatility provided more relevant information.

Due to the development of volatility indices or implied volatility, some researcher start to analyzing the relationships between volatility indices across different index markets, such as, volatility spillover and market integration (Äijö 2008). Moreover, it is known that the rate of change of market volatility is much higher than the rate of change of market return. Therefore, cross-market volatilities should reflect the dynamics of market interdependence much better than market returns.

In addition, some researchers suggest that the implied volatility reflects the investors' expectation on future market volatility better. Moreover, it contains more market information than the realized volatility and model-based volatility. One of the most well-known implied volatility is the CBOE volatility index, VIX, which was introduced in 1993 by Chicago Board Options Exchange (CBOE). The volatility index is often referred as the "fear index" which can measure 30-day expected volatility and have been considered as a direct measure of market uncertainty. If the volatility index is higher, it implies that investors expect the market to have higher volatility in the future. Moreover, CBOE introduced the volatility index of crude oil, gold and currencies in 2008 so it could provide new view of information transmission.

Regarding the methodology to apply over the implied volatility that acts as the variable, the problem occurs when investigating the spillover effect because the contemporaneous spillover cannot be identified on the ground of the endogeneity problem. Most of the spillover studies used the lead-lag dynamic such as VAR and GARCH but they failed to capture contemporaneous spillover. In additional, they use correlation analysis to investigate in contemporaneous spillover. However, correlation analysis cannot point out the direction. To solve the problem, Rigobon (2003) could identify the contemporaneous spillover effects with the direction by using the heteroskedasticity approach. These method allow us to understand the contemporaneous spillover among commodities

As mentioned above, this research shall use the CBOE volatility index and follow Badshah et al. (2013)'s study. This research will examine the information transmission among the oil, exchange rate and gold markets by applying the heteroskedasticity approach on the volatility indexes in the period between 2008 to 2013 The objective of this research is to identify the casual spill-over effects between crude oil, gold, and exchange rate volatility.

2. Literature Review

There are many empirical studies on volatility spillover. Most studies have been concerned with the volatility spillover between commodity market and equity market. However, the volatility spillover among commodities cannot be neglected.

2.1 Commodity and Equity Markets

Xu and Fung (2005) investigated the linkage between U.S. and Japanese market in future trading of gold, silver and platinum. They applied the bivariate asymmetric GARCH model and found the strong price transmission and strong volatility spill over across the U.S and Japanese markets. Tully and Lucey (2007) used the asymmetric power GARCH model to study the relationship between macroeconomic and gold market. They found that only a few variables could impact gold prices, but the US dollar could impact the gold volatility. Sjaastad (2008) examined the relationship between the gold prices and major exchange rates (Dollar, Euro and Yen) by using the forecast error data method. The result showed that the change of the US dollar had affected the gold markets or the gold market dominated by the US Dollar. Baur and McDermott (2010) investigated the role of gold in the financial markets. They tried to find whether gold was a safe haven against the stocks of major emerging and developing countries. The result showed the 'yes' answer to major European stock markets and the US. Apergis and Miller (2009) studied the oil prices and the market returns. They studied in 8 countries such as France, Germany, the United Kingdom, and the United States of America by applying both the Vector autoregressive model and the Vector error correction model. The result showed that the market return did not respond to the oil shock. Arouri et al. (2011) used the VAR-GARCH model to investigate the volatility spillover between oil prices and the stock market returns. They found that there had been the volatility spillover among oil and stock prices in Europe and the United States of America. Zhang et al.(2008) studied the spillover effect between the US dollar and oil prices by applying the VAR model, the Co-integration and the ARCH models. They investigated in three dimensions: the mean spillover, the risk spillover and the volatility spillover. They pointed out that there had been a co-integration relationship between the US dollar and oil prices. However, volatility spillovers are much insignificant as the risk spillover.

2.2 Spillover between crude oil and gold

The volatility spillover among the commodities is an interesting topic for investors and policy makers. Both crude oil and gold are two important and large commodities. Previously, some researches pointed out the relationship between them but now a few researches have been available on this topic. This research has found that most studies on in volatility spillover investigated their relationship by using the lead-lag relationship and the traditional prices. Lee et al. (2012) scrutinized the relationship between crude oil and gold futures during 1994 to 2008 by adopting the applied momentum threshold error-correction model with the generalized autoregressive conditional heteroskedasticity. They found the asymmetric long-run adjustment between oil and gold prices. Zhang and Wei (2010) studied the cointegrative and causality relationship between crude oil market and gold market during 2000 to 2008. The result showed that there had been positive correlation and the long term equilibrium between them. In additional, Juan (2013) investigate that Is gold a hedge or safe haven against oil price movements? He used the weekly data from January 2000 to September 2011. From his copula methodology reveal that there are positive and significant average dependence between gold and oil, which would indicate that gold cannot hedge against oil price movements

2.3 Implied volatility indices

The newly published volatility indexes, namely, the OVX (crude oil volatility index), the EVZ (foreign exchange rate volatility) and the GVZ (gold price volatility index), have emerged the studies on the relations between them instead of prices. M.-L. Liu et al. investigated the uncertainty interaction between oil and other markets by using OVX, VIX, EVZ and GVZ. The index data were analyzed by the generalized forecast error variance decomposition (GVDs) and the generalized impulse response functions (GIRFs) and found no strong long-run relationship between them. Moreover, Janne Ä also investigates in topic of implied volatility which is VDAX, VSMI and VSTOXX volatility indices. The underlying stock indices are the German general index (DAX), the Swiss general index (SMI) and the pan-European blue chip index (Dow Jones EuroStoxx50). He applied the causality test and vector autoregressive analysis (VAR) to analyze the transmission of implied volatility term structures. The result shows the correlation structures indicate that they are closely correlated to each other. In additional, Peng and Ng (2012) examine the cross-market dependence among five popular equity indices (S&P 500, NASDAQ 100, DAX 30, FTSE 100, and Nikkei 225) which are (VIX, VXN, VDAX, VFTSE, and VXJ). The results also show that dependence between volatility indices is more easily influenced by financial shocks and reflects the instantaneous information faster than the stock market indices. Moreover, Sari et al. (2010) examine the information transmission among oil, gold, silver, dollar/euro exchange rate markets, and volatility index (VIX) as the indicator of global risk perception. They found that VIX have a significantly suppressing effect on oil prices in the long run. Moreover, Qadan and Yagil (2011) investigate the relationship between volatility index (VIX) and price of gold future. They apply Generalized AR Conditional Heteroscedasticity (GARCH) family that allows for time variation. Then obtain the squared residuals of each estimated model and then construct the series of squared residuals standardized by conditional variances. They found bidirectional causality between them.

From the literature review, there are few literatures on spillover among commodities. Specifically, the literature on spillover among gold, oil and exchange rate are there. This research will utilize the heteroskedasticity technique to investigate the contemporaneous spill-over effect.

3. Methodology

Following Badshah et al. (2013), this study uses the identification through heteroskedasticity technique to examine the volatility spill over among OVX, GVZ and EVZ. The identification through heteroskedasticity is the method that was developed by Roberto Rigobon (2002). He claimed that the reduced-form Vector autoregressive could not identify the contemporaneous spillover. As the result, Structural vector autoregressive (equation (2)) is applied.

As the result, this paper estimate a “structural form VAR” that can identifies the contemporaneous spill-over between implied volatilities by relying on their conditional heteroskedasticity. In this model, shifts in conditional variances of the shocks to the variable have implications for covariance between the variables that depend on their responsiveness to one another. In overview, this model identifies the contemporaneous spill-over by placing cross-restrictions on evolution of second moments. Moreover, the model allows us to discover the source of current movement in a given variable. In particular, whether the variable was driven by a shock of itself, or shock to another variable?

In additional, This model imposes some assumption such as the market depend linearly on each other and the model have assumed simple GARCH (1,1). However, with these simplifications the model is useful in understanding the dynamics and spillovers of the variable. According to Rigobon (2003b), the model could be estimated including some common shocks which can be extend in future research.

3.1 Structural-form VAR

We are interested in estimating relationships between three variables so assume that the dynamics of three implied volatilities are described by the following

$$A\Delta IV_t = c + \Phi(L)\Delta IV_t + \varepsilon_t \tag{2}$$

$$A = \begin{pmatrix} 1 & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & 1 & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & 1 \end{pmatrix} \qquad \Delta IV_t \equiv \begin{pmatrix} \Delta OVX_t \\ \Delta GVZ_t \\ \Delta EVZ_t \end{pmatrix}$$

Where ΔIV_t is a vector of change in each implied volatility indices.

C is vector of constant.

$\Phi(L)$ is vector of polynomial of lag operator.

ε_t is the residual term.

A is the contemporaneous spillover between ΔOVX , ΔGVZ and ΔEVZ

From equation (2), the off-diagonal element are coefficients that measure contemporaneous spillover between ΔOVX , ΔGVZ and ΔEVZ which is the important variable of this research. α_{xy} is variable that represents the contemporaneous spillover from x to y. For example, α_{12} is the spillover from ΔOVX to ΔGVZ . α_{13} is the spillover from ΔOVX to ΔEVZ . α_{21} is the spillover from ΔGVZ to ΔOVX .

However, the problem is that we cannot identify the A because of the endogeneity problem. Therefore, we have to identify matrix A from heteroskedasticity properties in the data. Moreover, we have to make two assumptions as following to help in identify the A.

The residual term has the standard zero-mean property ($E(\varepsilon_t) = 0$) and contemporaneously and serially uncorrelated ($E(\varepsilon_{it}\varepsilon_{jt-k}) = 0$).

The variance of residual term exhibit conditional heteroskedasticity ($\varepsilon_t \sim N(0,H_t)$) H_t are diagonal and $h_t \equiv Diag(H_t)$ which h_t follow the $GARCH(1,1)$ process.

The $GARCH(1,1)$ is showed in equation (3)

$$h_t = \psi_h + \Gamma h_{t-1} + \Lambda \varepsilon_{t-1}^2 \tag{3}$$

3.1.1 Identification A

Due to conditional heteroskedasticity in the data (two assumptions above), we begin to identify the model by time the A^{-1} to equation (2)

$$\Delta IV_t = c^* + \Phi^*(\mathrm{L})\Delta IV_t + \eta_t \tag{4}$$

So $c^* = A^{-1}c$, $\Phi^*(\mathrm{L}) = A^{-1}\Phi(\mathrm{L})$, $\eta_t = A^{-1}\varepsilon_t$

The equation (4) showed the reduced form VAR. Consequently, we know that the residual term is conditional heteroskedasticity as mentioned in assumption 2. Hence, if residual term of structural form are exhibit in GARCH (1, 1), the reduced form of reduced form (η_t) should be exhibit in GARCH (1, 1) as well

The matrix A will be identified from η_t which is $\eta_t \sim N(0,\Omega_t)$. $vech(\Omega_t)$ (half-vectorization) was followed

$$\begin{pmatrix} \Omega_{OVX,OVX,t} \\ \Omega_{OVX,\mathrm{GVZ},t} \\ \Omega_{OVX,\mathrm{EVZ},t} \\ \Omega_{\mathrm{GVZ,GVZ},t} \\ \Omega_{\mathrm{GVZ,EVZ},t} \\ \Omega_{\mathrm{EVZ,EVZ},t} \end{pmatrix} = B_1\Psi_h + B_1\Gamma(\mathrm{B}^2)^{-1}\begin{pmatrix} \Omega_{OVX,OVX,t-1} \\ \Omega_{\mathrm{GVZ,GVZ},t-1} \\ \Omega_{\mathrm{EVZ,EVZ},t-1} \end{pmatrix} + B_1\Lambda(\mathrm{B}^2)^{-1}\begin{pmatrix} \eta^2{}_{OVX,t-1} \\ \eta^2{}_{\mathrm{GVZ},t-1} \\ \eta^2{}_{\mathrm{EVZ},t-1} \end{pmatrix} \tag{5}$$

Where:

$$A^{-1} = B = \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix} \quad B_1 = \begin{pmatrix} b^2{}_{11} & b^2{}_{12} & b^2{}_{13} \\ b_{11}b_{21} & b_{12}b_{22} & b_{13}b_{23} \\ b^2{}_{21} & b^2{}_{22} & b^2{}_{23} \\ b_{11}b_{31} & b_{12}b_{32} & b_{13}b_{33} \\ b_{21}b_{31} & b_{22}b_{32} & b_{23}b_{33} \\ b^2{}_{31} & b^2{}_{32} & b^2{}_{33} \end{pmatrix}$$

The equation (5) above is Multivariate GARCH (1, 1) with restriction on parameter. Hence, we will estimate the model by using Maximum Likelihood.

Under this approach, we can estimate A which are contemporaneous response coefficient. However, A is on left hand side of equation (2) so to interpret the result we have to rewrite the left hand side of equation (2). From left hand of equation (2) we can rewrite to equation (6) and (7)

$$\Delta OVX + \alpha_{12}\Delta GVZ + \alpha_{13}\Delta EVZ \tag{6}$$

$$\Delta OVX = -\alpha_{12}\Delta GVZ - \alpha_{13}\Delta EVZ \tag{7}$$

We can see that the contemporaneous response coefficient is in negative sign. Hence, if the contemporaneous response coefficient be in negative sign, it mean that two variable have the positive relationship.

Additionally, before we perform the SVAR as mention above, we will estimate reduced form VAR and perform Granger causality test to observe the lead-lag relationship. Granger causality test will investigate that whether the volatility X is granger caused by volatility Y.

3.2 Comparison to multivariate GARCH

According to the model, we assume the residual term of reduced form VAR follow GARCH (1, 1). Then discover matrix A by estimate the multivariate GARCH (1, 1) from Maximum likelihood method. Hence, it may be useful to compare the model with other multivariate GARCH.

Firstly, the following Bollerslev (1990), Multivariate Generalized ARCH model with constant correlation model. This model assumes that conditional correlation between variable are constant. With constant correlation, the model cannot capture the shift in conditional correlation between variable. However, our model can capture this behavior.

Secondly, DCC-GARCH model of Engel (2002) is similar to our model. The model assume that the correlation coefficient between two variables is drive by their own lagged and other lagged reduced form residual.

In overview, our model has advantage that it can estimate the contemporaneous response of variable to another variable.

3.3 Data

This research uses daily data which cover the sample period from 1 August 2008 to 1 December 2013 and obtain data from Chicago Board Option Exchange (CBOE). CBOE used the VIX method to calculate the commodity volatility index and currency volatility index in 2008. This research uses the variable which is crude oil volatility index (OVX), gold volatility index (GVZ) and exchange rate volatility index (EVZ).

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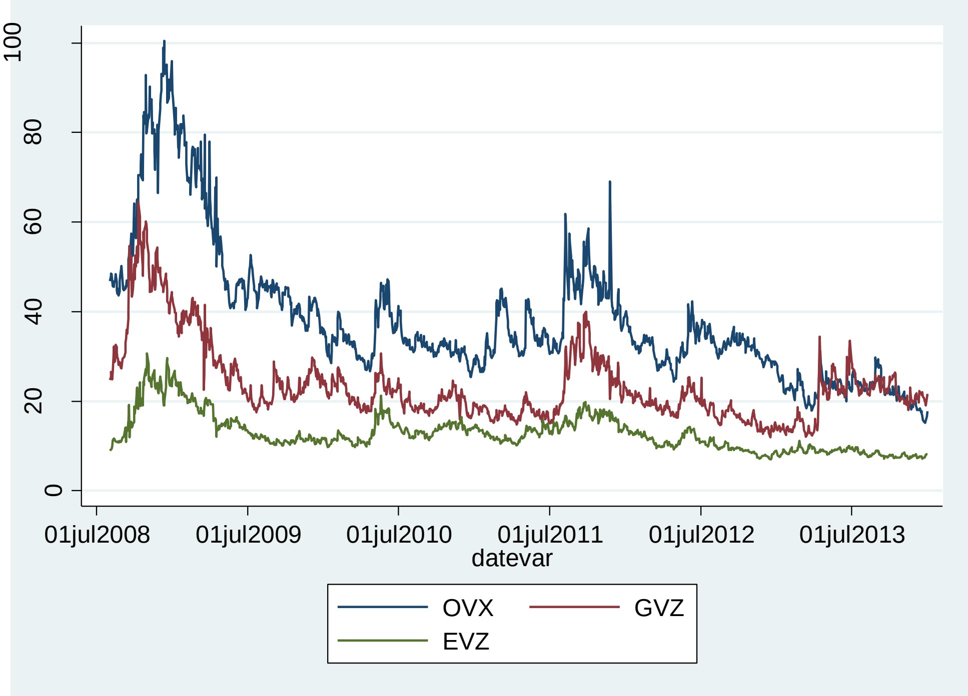
Figure 1 : Time series plot of the OVX, GVZ, and EVZ



The figure 1 is time series plot of three implied volatilities which is OVX, GVZ and EVZ cover the sample period from 1 August 2008 to 1 December 2013. Overview, we can see that there are commonalities in the levels among these three variables. Firstly, we can observe very high volatility in September 2008 when the bankruptcy of Lehman brothers which trigger the global financial crisis. The volatilities indices are increase greatly which show that the crisis spread into commodities market. Moreover, we also observe high volatility in 2010 which are related to weak economic recovery. In additional, the third high volatilities period is in August 2011 which is related the fear of US and European debt default. Hence, it is indicated that the implied volatility indices are related to economic event and can measure the market uncertainty. However, these three volatility indices are not always response the same even though they are faced the same shocked. The reason is each implied volatility indices will response to the specific shock.

Table 1: Descriptive statistics of the OVX, GVZ, and EVZ

	EVZ	GVZ	OVX
Mean	12.7560	23.5306	38.3373
Median	11.8300	21.2200	33.6800
Maximum	30.6600	64.5300	100.4200
Minimum	6.9900	11.9700	15.2000
Std. Dev.	4.1128	8.5848	15.5494
Skewness	1.2665	1.8036	1.6094
Excess Kurtosis	4.7960	6.5464	5.6267
J.B	548.07***	1457.42***	979.46***
ADF	-1.7397	-2.8064*	-2.1041

Notes: ADF is the t-statistics for the Augmented Dickey-Fuller test. ***, ** and* denote significance at 1%, 5% and 10% levels, respectively.

Table 2: Descriptive statistics of the logarithmic change of OVX, GVZ, and EVZ

	ΔEVZ	ΔGVZ	ΔOVX
Mean(*10^{-5})	-6.53	-9.76	-71.1
Median	-0.0024	-0.0058	-0.0047
Maximum	0.2814	0.4807	0.4249
Minimum	-0.4749	-0.4459	-0.4399
Std. Dev.	0.0469	0.0610	0.0516
Skewness	-0.1742	0.9742	0.8177
Excess Kurtosis	15.33	13.54	15.97
J.B	8644.9***	6521.4***	9707.2***
ADF	-16.3742***	-30.6724***	-43.8005***

Notes: ADF is the t-statistics for the Augmented Dickey-Fuller test. ***, ** and* denote significance at 1%, 5% and 10% levels, respectively.

The summary statistic for OVX, GVZ and EVZ between 1 Aug 2008 to 1 Dec 2013 is presented in table 1.The result show that OVX has highest mean and median while EVZ has lowest mean and median. The standard deviations show that the OVX is more change than others. Moreover, the three indices show positively skewed. The Kurtosis of three indices are larger than 3 so they are leptokurtic distribution. In additional, the jarque-bera test does not support the supposition that each variable has a normal distribution, since the null hypothesis that each variable has a normal distribution is rejected.

Table 2 report the summary statistic for ΔOVX, ΔGVZ and ΔEVZ which are the logarithmic change ($\ln(V_t / V_{t-1})$). Both mean and median of ΔOVX, ΔEVZ and ΔGVZ show negative value but very close to zero. ΔGVZ and ΔOVX show positively skewed but ΔEVZ show negatively skewed. The Kurtosis of three indices are larger than 3 so they are leptokurtic distribution. Furthermore, Jarque-bera test also show that none of logarithmic change in volatility indices follow standard normal distribution.

Moreover, this research methodology is based on VAR model so we have to test whether the implied volatility indices are stationary. Hence, we use Augmented Dickey Fuller (ADF) test which are unit root test for time series data. Table1 was provided Augmented Dickey Fuller (ADF) test on volatility indices level. The ADF show that we cannot reject null hypothesis for OVX and EVZ but reject null hypothesis of GVZ at 10% significance level. For table2, ADF test show that we can reject null hypothesis of ΔOVX, ΔGVZ and ΔEVZ at 1% significance level. Hence, OVX, GVZ and EVZ are non-stationary on level of volatilities index but stationary on the logarithmic change level.

4. Results and Discussion

4.1 The Reduced Form VAR

Before computing the Structural form VAR, we compute the reduced form VAR to investigate the lead-lag relationship. The reduced form VAR model can be derived by multiply A^{-1} to equation (2).The VAR model is interdependent and dynamic system models which treat each endogenous variable in the system as a function of their lagged term.

However, the optimal lag length of VAR has to be estimate before computing the VAR. In order to determine the lag order of VAR, we have to use some criteria such as Akaike information criterion (AIC), Schwarz information criterion (SIC) and sequential modified LR test statistic (LR). This research will choose the optimal lag length of VAR by Akaike information criterion or has the lowest Akaike information criterion (AIC).

After set maximum number of lags equal to 12, we can determine number of optimal lags from the lowest value of AIC. The results for the determination of the appropriate number of lags to be used in the VAR (p) system show that Akaike's (AIC) information criterion, final prediction error (FPE) and sequential modified LR test statistic (LR) test suggest the lag length of eight to be appropriate for the VAR (p) model, Schwartz's (SIC) information criteria suggest lag lengths of two respectively. The result show the higher lag has lower AIC value. However, AIC is lowest at 8 lag (-9.4895) and start increasing from 9 lag to 12 lag. Hence, AIC shows that an optimal lag length is 8

In additional, the result of VAR test for ΔOVX, ΔEVZ and ΔGVZ by using 8 lags is reported in table 3. The rows denote the variables and their lags. Corresponding to each variable’s lag, there are two rows. The first row indicates the coefficient in the estimated VAR model and the second row indicates the value of t-statistics. For ΔOVX equation, the results show significant in the first lags (day one) for three variables. However, in eight lag, the result show significant in ΔGVZ. For ΔEVZ equation, the results show significant in the first lags for ΔOVX and ΔEVZ. On the other hand, in eight lag, the result show significant in ΔEVZ. For ΔGVZ equation, the results show significant in the first lags for three variables. On the contrary, in eight lag, the result show significant in ΔGVZ

Table 3: VAR table of OVX, GVZ, and EVZ for 8 periods

	ΔOVX	ΔEVZ	ΔGVZ
C	-0.0011	-0.0003	-0.0003
	[-0.8442]	[-0.2443]	[-0.1676]
ΔOVX_{t-1}	-0.2122***	0.0960***	0.0967***
	[-7.2483]	[3.5924]	[2.7647]
ΔOVX_{t-2}	-0.0197	-0.0095	0.0637*
	[-0.6531]	[-0.3451]	[1.7613]
ΔOVX_{t-3}	-0.1169***	-0.0253	0.0124
	[-3.8854]	[-0.9199]	[0.3459]
ΔOVX_{t-4}	-0.0730**	0.0200	0.0388
	[-2.4184]	[0.7272]	[1.0725]
ΔOVX_{t-5}	-0.0927***	0.0044	-0.0355
	[-3.0696]	[0.1605]	[-0.9814]
ΔOVX_{t-6}	-0.0986***	0.0018	-0.0435
	[-3.2856]	[0.0658]	[-1.2120]

ΔOVX_{t-7}	-0.0686**	-0.0040	-0.0064
	[-2.2817]	[-0.1479]	[-0.1773]
ΔOVX_{t-8}	0.0147	-0.0144	0.0155
	[0.5051]	[-0.5419]	[0.4437]
ΔEVZ_{t-1}	0.1115***	-0.1414***	0.0651*
	[3.4855]	[-4.8418]	[1.6968]
ΔEVZ_{t-2}	-0.0581*	-0.0706**	0.0034
	[-1.7803]	[-2.3732]	[0.0869]
ΔEVZ_{t-3}	0.0379	-0.0969***	0.0198
	[1.1649]	[-3.2627]	[0.5085]
ΔEVZ_{t-4}	0.0150	0.0376	0.1130***
	[0.4636]	[1.2734]	[2.9083]
ΔEVZ_{t-5}	0.0204	-0.1287***	0.0245
	[0.6276]	[-4.3409]	[0.6307]
ΔEVZ_{t-6}	0.0777**	-0.0420	-0.0068
	[2.3840]	[-1.4130]	[-0.1747]
ΔEVZ_{t-7}	0.0208	0.0007	0.0267
	[0.6387]	[0.0256]	[0.6833]
ΔEVZ_{t-8}	-0.0072	-0.1241***	0.0034
	[-0.2265]	[-4.2437]	[0.0907]
ΔGVZ_{t-1}	0.0472*	0.0225	-0.1342***
	[1.8756]	[0.9796]	[-4.4484]
ΔGVZ_{t-2}	0.0053	-0.0085	-0.1681***
	[0.2109]	[-0.3699]	[-5.5238]
ΔGVZ_{t-3}	0.0757***	0.0097	-0.0845***
	[2.9451]	[0.4139]	[-2.7425]
ΔGVZ_{t-4}	0.0073	-0.0281	-0.0799**
	[0.2851]	[-1.1939]	[-2.5795]
ΔGVZ_{t-5}	0.0270	0.0383	-0.0619**
	[1.0489]	[1.6295]	[-2.0034]
ΔGVZ_{t-6}	-0.0130	-0.0243	-0.0446
	[-0.5076]	[-1.0358]	[-1.4453]
ΔGVZ_{t-7}	0.047160*	0.029256	-0.026725
	[1.85529]	[1.26139]	[-0.87744]
ΔGVZ_{t-8}	0.052956**	-0.011857	-0.050917*
	[2.10638]	[-0.51689]	[-1.69022]

Notes: : This table reports the results for reduced-form VAR as defined in equation(4) .The top entry in each row show the coefficient of VAR estimation and the second entry show the value of the t-statistic. ***, ** and* denote significance at 1%, 5% and 10% levels, respectively.

The reduced-form VAR result show that the VAR (8) model's coefficient show significant on themselves variable. ΔOVX equation shows that coefficient of ΔGVZ is significant at 5% level which can imply that ΔOVX and ΔGVZ has lead-lag relationship. For ΔEVZ equation and ΔGVZ equation, coefficient shows significant on themselves variable. Moreover, Granger causality tests are used to examine the direction of the causality between the implied volatility. Normally, Granger causality test will test based on lag order selection which is 8 lag. However, the results of VAR show highly significant on 1 lag. Hence, the result of Granger causality test on 1 lag and 8 lag should be provided.

4.2 Granger Causality Test

One benefit of VAR model is forecasting. The structure of the VAR model provides information about a variable's forecasting ability for other variables. Granger (1989) creates the test whether one group of variable can help to predict another group of variable. If a group of variable1 is helpful to predict group of variable2, group of variable1 is said to granger-cause group of variable 2. The test statistic of granger causality with 1-day lag length and 8-day lag length is reported in table 4. The result show unidirectional causality between ΔEVZ and ΔGVZ which is ΔEVZ granger cause ΔOVX, but not vice versa. On 1-day lag length ΔEVZ granger cause ΔGVZ at 0.05 significant levels but on 8-day lag length, ΔEVZ granger cause ΔGVZ at 0.1 significant levels. Moreover, there is bidirectional causality between ΔGVZ and ΔOVX. ΔGVZ granger cause ΔOVX at 0.01 significant levels and ΔOVX granger cause ΔGVZ at 0.05 significant levels. In additional, ΔEVZ and ΔOVX also has bidirectional causality relationship. On 1-day lag length ΔEVZ granger cause ΔOVX at 0.01 significant levels and ΔOVX granger cause ΔEVZ at 0.01 significant levels. On 8-day lag length, ΔEVZ granger cause ΔOVX at 0.01 significant levels and ΔOVX granger cause ΔEVZ at 0.05 significant levels.

In overview, the exchange rate volatility index (ΔEVZ) granger cause both ΔOVX and ΔGVZ. These result shows that uncertainty information in exchange rate market could be transmitted to oil and gold market. Similarly, it is found that change uncertainty information in oil market could be transmitted to exchange rate market and gold market. However, it is found that changes in ΔOVX are significantly leaded by both gold and exchange rate volatility indices. While, the same situation is also happen with Gold. The reason may because of crude oil price and Gold price are crushed down during hamburger crisis. Hence, the investor in both commodities market becomes more sensitive to uncertainty information from other markets.

Table 4: Granger Causality Tests

	1 Lags		8 Lags	
Null Hypothesis:	F-Statistic	P-Value	F-Statistic	P-Value
ΔGVZ does not Granger Cause ΔOVX	7.09238***	0.0078	3.39734***	0.0007
ΔOVX does not Granger Cause ΔGVZ	5.42926**	0.0199	2.10827**	0.0323
ΔEVZ does not Granger Cause ΔOVX	18.4684***	0.0000	4.07420***	0.0000
ΔOVX does not Granger Cause ΔEVZ	15.7518***	0.0000	2.20877**	0.0245
ΔEVZ does not Granger Cause ΔGVZ	3.88981**	0.0488	1.91509*	0.0541
ΔGVZ does not Granger Cause ΔEVZ	2.65018	0.1038	1.43895	0.1756

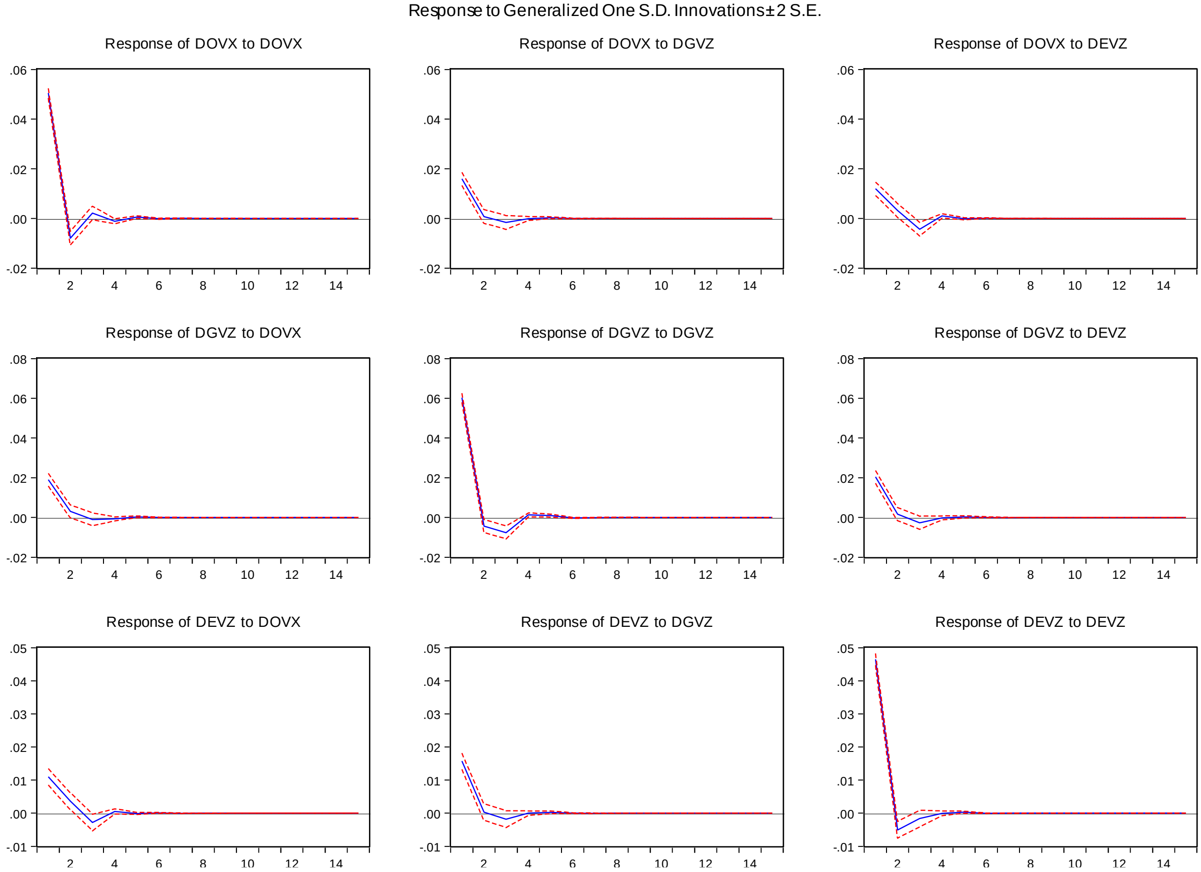
Notes: This table reports the results for granger causality tests on reduced-form VAR using 8 lags. ***, ** and* denote significance at 1%, 5% and 10% levels, respectively.

The result from Granger causality showed that the investor in exchange rate and commodities market pay attention to other market. Generally, both exchange rate and commodities are related together. The result doesn't seem surprise because the exchange rate can affect the gold and oil market so the exchange rate volatility may affect the gold and oil volatility. The reason is that oil and gold are denominated in US dollar, and thus, the dollar exchange rate may co-drive both of them simultaneously. During the expected inflation, investors may move from dollar-denominated soft assets such as stocks to dollar-denominated physical assets such as oil and gold. It is well known that investors use gold, as a safe haven in their flight to safety when the US dollar weakens against the other major currencies, especially euro. Moreover, depreciating dollar against the euro can also push up oil prices. In additional, the gold and oil volatility also affect each other. This may because gold and oil are determined by some common factors. On the contrary, there is only exchange rate volatility that doesn't affect by gold market volatility.

4.3 Generalized Impulse-Response

Moreover, I perform the generalized impulse-response functions, which reveal the impact of one standard deviation shock of one variable to another variable. The test statistic is reported in figure 3.The first column show impact of ΔOVX to others variable. While the second column show impact of ΔOVX and last column show impact of ΔEVZ. The result shows that each of variables has largest response to its own shock which turn to be significantly negative since the second day. This clearly implies that investors will overreact to unexpected volatility information in its markets. Specifically, GVZ has the largest response to its own shock. On the other hand, GVZ have positive impact of one standard deviation shock on EVZ and OVX but almost disappear in third day. Figure 3: Generalized impulse response of ΔOVX, ΔGVZ and ΔEVZ (the dotted lines represent two standard error confidence bounds). Similarly, EVZ also have positive impacts of one standard deviation shock on GVZ and OVX. In additional, OVX also have positive impacts of one standard deviation shock on GVZ and EVZ.

Figure 2 : Generalized impulse response of ΔOVX, ΔGVZ and ΔEVZ (the dotted lines represent two standard error confidence bounds).



Moreover, I perform the generalized impulse-response functions, which reveal the impact of one standard deviation shock of one variable to another variable. The test statistic is reported in figure 2.The first column show impact of ΔOVX to others variable. While the second column show impact of ΔOVX and last column show impact of ΔEVZ. The result shows that each of variables has largest response to its own shock which turn to be significantly negative since the second day. This clearly implies that investors will overreact to unexpected volatility information in its markets. Specifically, GVZ has the largest response to its own shock. On the other hand, GVZ have positive impact of one standard deviation shock on EVZ and OVX but almost disappear in third day. Figure 3: Generalized impulse response of ΔOVX, ΔGVZ and ΔEVZ (the dotted lines represent two standard error confidence bounds). Similarly, EVZ also have positive impacts of one standard deviation shock on GVZ and OVX. In additional, OVX also have positive impacts of one standard deviation shock on GVZ and EVZ.

The impacts of innovations in other volatility indices on volatility are also positive and significant. However, the influences are weaker and last for a shorter time (most die out since the second day), implying that the cross-market uncertainty transmission among the oil, exchange rate, and gold markets is direct and transient.

4.4 Structural Form VAR

Secondly, the matrix A (contemporaneous spillover) from identification through heteroskedasticity method are reported in table 5. Matrix A will show contemporaneous of change in variable of top row on variable in the first column. Moreover, the coefficient in A have negative sign as A is on left-hand side of equation (2) (as described in equation (6) and (7)).

Table 5: Contemporaneous spill-over

	ΔOVX	ΔGVZ	ΔEVZ
ΔOVX	1	0.1174***	-0.1483***
ΔGVZ	-0.4132***	1	-0.3313***
ΔEVZ	-0.1287***	0.0040***	1

Notes: This table reports the contemporaneous relation Matrix A as defined in equation (2). ***, ** and* denote significance at 1%, 5% and 10% levels, respectively.

The primary finding of structural form VAR is that all of contemporaneous response coefficients are significant. This result indicates that there are strong linkages across commodities market volatility and exchange rate market volatility.

The first column report contemporaneous casual effect of ΔOVX on the ΔGVZ and ΔEVZ. The result indicate that increase in ΔOVX 1% lead to contemporaneous increase in ΔGVZ 0.41%.Moreover,we also observe the contemporaneous casual effect from ΔOVX to ΔEVZ,with the 0.12 coefficient. These finding indicate that there is instantaneous spill-over from oil market volatility to gold market volatility and exchange volatility

The second column show contemporaneous casual effect of ΔGVZ on the ΔOVX and ΔEVZ. The result shows that contemporaneous casual effect from ΔGVZ on ΔEVZ, with 0.004 coefficients. This indicated that there is some contemporaneous casual effect of gold volatility on exchange rate volatility. However, we observe negative relationship of 0.11 when consider the casual effect from ΔGVZ on ΔOVX.

The last column show contemporaneous casual effect of ΔEVZ on the ΔOVX and ΔGVZ. The result shows the instantaneous spillover from ΔEVZ to ΔOVX about 0.12. Moreover, we also observe the instantaneous spillover from ΔEVZ to ΔGVZ about 0.33

In the overview, Table 5 shows that there is bi-directional instantaneous spill-over from ΔOVX to the ΔGVZ and ΔOVX to ΔEVZ. In additional, there is the instantaneous spill-over from ΔEVZ to ΔGVZ. Comparing to result in table 4, the contemporaneous spillover is consistent with Granger causality. However, we found the instantaneous spill-over from ΔGVZ to ΔEVZ with a little coefficient. Hence, we can conclude that the exchange rate volatility is instantaneous cause the gold and oil market volatility. In additional, the oil market volatility also instantaneous causes exchange rate and gold market volatility. There may be plausible explanations for this finding. As pointed out by Pindyck and Rotemberg (1990), traders in different commodity markets may be responding similarly to the same noneconomic factors.

Moreover, the result show some different from Badshah et al. (2013). Badshah et al. (2013) result show instantaneous spill-over from ΔEVZ to ΔGVZ, with 0.11 coefficients. This is consistent with our result which shows instantaneous spill-over from ΔEVZ to ΔGVZ with 0.33 coefficients. However, Badshah et al. show instantaneous spill-over from ΔGVZ to ΔEVZ with 0.13 coefficients while our results show some contemporaneous casual effect of gold volatility on exchange rate volatility with 0.004 coefficients. The difference may from the data, Badshah et al use sample from 2008 to 2011. While, our result use sample from 2008 to 2013.The reason is the rise of GVZ in 2013.The data show two biggest one-day moves in the year 2013 for the GVZ Index. On 2013, April 12, the GLD ETF fell 4.7% and the GVZ rose 39.4%. On 2013, April 15, the GLD ETF fell another 8.8%, and the GVZ Index rose another 61.7% (the biggest one-day move ever for the index). Due to the rise of GVZ, it can reflect that investor in Gold market may pay more attention to other markets. Our result also show that the coefficient of contemporaneous spill-over of OVX and EVZ to GVZ are very high compared to other coefficient.

5. Conclusions and Recommendations

This paper has examined the relationship among the implied volatility indices, which has employed the reduced form VAR and the identification via the heteroskedasticity approach.

The granger causality test and the generalized impulse response have also provided the reduced form VAR while the identification by the heteroskedasticity method showed the contemporaneous spillover between this implied volatility, and the reduced form VAR showed lead-lag relationship. The results showed the bi-direction spillover effect from OVX to GVZ and OVX to EVZ. In additional, there was the instantaneous spill-over from ΔEVZ to ΔGVZ. Hence, the increase in exchange rate volatility led to the increase in gold and oil volatility. Moreover, the increase in gold volatility led to the decrease in oil volatility. Furthermore, the result from identification via the heteroskedasticity approach was consistent with that of the granger causality test. However, the identification through heteroskedasticity method has provided both direction and magnitude of the spill-over. Our empirical results support the notion of significant volatility spillover across commodity markets.

Finally, the volatility index linkage could reflect the investors' expectation of the future market volatilities. These finding results thus are useful for people who have planned to invest in OVX and GVZ options and futures. To invest in these securities, the investor should pay attention on OVX, EVZ and GVZ. Moreover, understanding the spillover effect can make the investors implicate their portfolios.

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